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Failure mechanism and control technology of longwall coalface in large-cutting-height mining method

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ABSTRACT

The stability control of longwall coalface is the key technology of large-cutting-height mining method. Therefore, a systematic study of the factors that affect coalface stability and its control technology is required in the development of large-cutting-height mining method in China. After the practical field observation and years of study, it was found that the more than 95% of failures in coalface are shear failure. The shear failure analysis model of coalface has been established, that can perform systematic study among factors such as mining height, coal mass strength, roof load, support resistance, and face flipper protecting plate horizontal force. Meanwhile, sensitivity analysis of factors influencing coalface stability showed that improving support capacity, cohesion of coal mass and decreasing roof load of coalface are the key to improve coalface stability. Numerical simulation of the factors affecting coalface stability has been performed using UDEC software and the results are consistent with the theoretical analysis. The coalface reinforcement technology of large-cutting-height mining method using the grouting combined with coir rope is presented. Laboratory tests have been carried out to verify its reinforcement effect and practical application has been implemented in several coal mines with good results. It has now become the main technology to reduce longwall coalface failure of large-cutting-height mining method.

1. Introduction

Large-cutting-height mining method of more than 3.5 m mining height is one of the main methods for thick-seam mining in China. Currently, the largest mining height is 7.3 m and the support capacity is 1800 million tons. Shendong and Jincheng mining area have the best use of large-cutting-height mining technology [1,2]. Generally, the mining height ranges from 6.5 to 7 m and the support capacity ranges from 1000 to 2000 million tons. Annual output of the panel is between 10 and 12 million tons and the highest one is 15 million tons. The main goal of large-cutting-height mining technology is to achieve high yield and high efficiency by increasing the advancing speed of longwall face [3,4]. However, in certain geologic conditions, rib spalling and roof falls in the unsupported area often occur. Because of the large tonnage of large-cutting-height mining equipment, once the rib spalling and roof falls cause the equipment to be out of alignment, the face advancing speed could be affected seriously that in turn affects the output [4]. Therefore, studying the failure mechanism and control technique of coalface in large-cutting-height mining method is of great significance.

2. Coalface failure model

2.1. Basic types of coalface failure

Through years of underground observation and research, two types of coalface failure have been identified as shown in Fig. 1 [5].

However, the actual failure mode is not limited to the two basic types and it may not be as clean and neat as shown in Fig. 1. They could be more diverse as shown in Fig. 2 [6,7].

The various types of coalface failures of panel 2612 in Dongpang Mine of Jizhong Energy Group are shown in Fig. 2. The upper failure and total failure account for more than 80% (Fig. 2a and d), upper and lower failure accounts for 16%, and their modes are shear failure (Fig. 1a). The upper and lower failure occurs due to the control effect of a relatively strong rock parting in the mid height of coal seam, although its failure mechanism is belonged to the shear failure (Fig. 2c). The upper part above the rock parting occurs as

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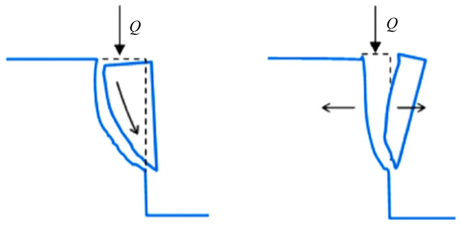


(a) Shear failure (b) Tension failure

Fig. 1. Basic types of coalface failure.

shear failure, while the lower part below it is tensile failure due to extrusion. The central failure belongs to the tensile failure, extruded at the center of the coalface (Fig. 2b). In general, tensile failure often occurs in the hard coalface, but this type is seldom seen. The above analysis shows that the coalface failure is mainly shear failure, which can be described by the shear failure model, as noted in Fig. 3.

2.2. Shear failure model of coalface

The shear failure surface of coalface is mainly a curved surface. In order to facilitate the research, it is simplified as block *a*, band *c*. The roof pressure is simplified as a uniform force with a load intensity *q*. Fig. 3 shows the failure model [8–11]. Based on the Mohr–coulomb strength theory, Eq. (1) is defined to describe the safety factor *K*. If *K* is less than 1, then the coalface would fail. Otherwise, the coalface is stable.

In Fig. 3, H is the cutting height; H_1 the shield support length; H_2 the face failure height; B the depth of face failure; q the roof of load; q_0 the horizontal capacity of shield support.

$$K = \frac{T}{S} \tag{1}$$

where K is the safety factor; T the shear stress; and S the shear strength.

As shown in Fig. 3,

$$\begin{aligned} S &= (Q+G)\cos\alpha - Q_0\sin\alpha \\ T &= cL + N\tan\varphi = \frac{cH_2}{\cos\alpha} + [(Q+G)\sin\alpha + Q_0\cos\alpha]\tan\varphi \end{aligned} \tag{2}$$

As shown in Eq. (2),

$$L = \frac{H_2}{\cos\alpha}$$

$$Q = qB = qH_2\tan\alpha$$

$$Q_0 = q_0H_1/2$$

$$G = A\gamma = \frac{1}{2}H_2^2\gamma\tan\alpha$$

$$N = (Q+G)\sin\alpha + Q_0\cos\alpha$$

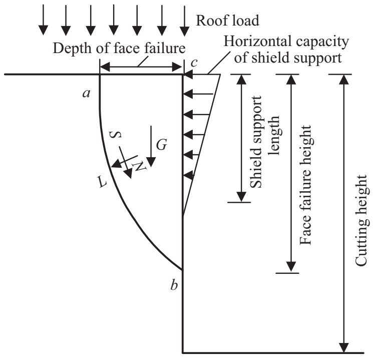


Fig. 3. Shear failure model of coalface.

where N is the positive pressure on failure surface; L the length of failure plane; q_0 the applied load of the flipper; H the height of coalface; H_1 the height of flipper; H_2 the failure height of coalface; G the weight of coalface failure block; γ the volume-weight of coal; α the angle between the failure surface and coalface; Q the roof pressure on coalface; Q_0 the horizontal force of flipper; c the coal cohesion; and φ the coal friction.

The stability coefficient of coalface can be represented by Eq. (3) below.

$$\begin{aligned} K = \frac{T}{S} &= \frac{\frac{cH_2}{\cos\alpha} + [(Q+G)\sin\alpha + Q_0\cos\alpha]\tan\varphi}{(Q+G)\cos\alpha - Q_0\sin\alpha} \\ &= \frac{[(Q+G)\sin\alpha + Q_0\cos\alpha]\tan\varphi + \mathrm{C}H_2\sec\alpha}{(Q+G)\cos\alpha - Q_0\sin\alpha} \end{aligned} \tag{3}$$

In longwall panels of large-cutting-height mining method, the height of caving zone increases with the increase of mining height. Simultaneously, the main roof develops upward, away from the face. Therefore, the roof pressure can be obtained using the estimate method.

The immediate roof load can be represented as Eq. (4) below.

$$Q_1 = \frac{H}{k_p - 1}\gamma L_1 \tag{4}$$

where k_p is the bulking factor; and L_1 the length of roof overhang, m.

The load of main roof and the additional strata can be represented as Eq. (5) below.

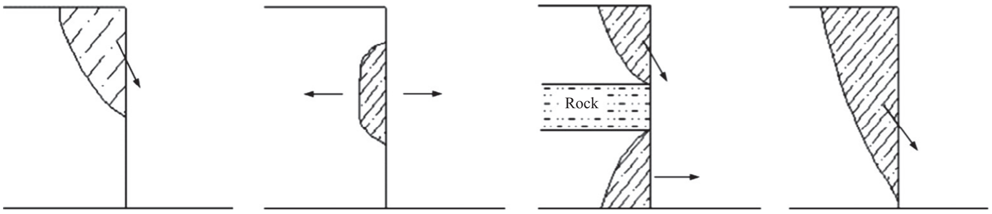
$$Q_2 = n\frac{H}{k_p - 1}\gamma L_2 \tag{5}$$

where $n = 1.5$ is the increasing in load modulus; and L_2 the length of broken main roof, m.

The total roof load is distributed between the support and coalface. Therefore, the load on the coalface is expressed by Eq. (6) below.

$$Q = \frac{H\gamma(L_1 + nL_2)}{(k_p - 1)} - L_B p \tag{6}$$

where L_B is the roof-control distance of support, m; and p the support strength, MPa.



(a) Upper failure (b) Central failure (c) Upper and lower failure (d) Total failure

Fig. 2. Failure mode of panel 2612 in Dongpang Mine.